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SEMI-ANNUAL PROGRESS REPORT

ON

A STUDY OF REACTIVE PLASMA DEPOSITED THIN FILMS

GRANT #NAG-1-414

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LANGLEY RESEARCH CENTER

by

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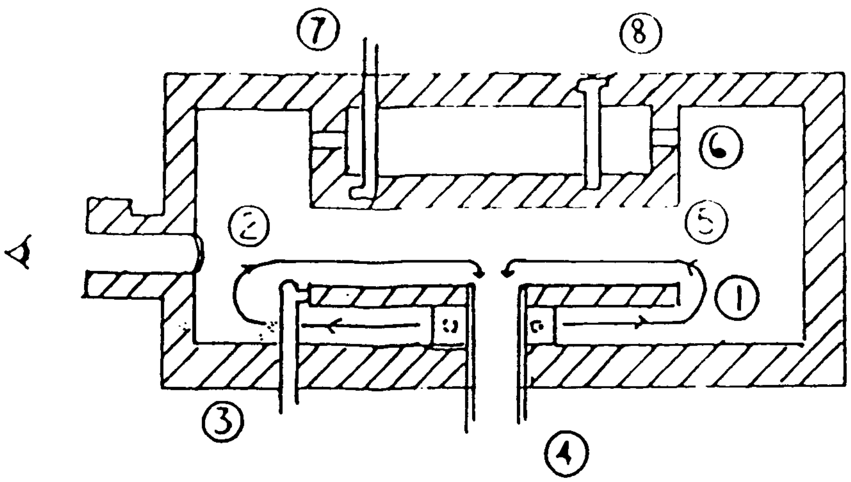
The goal of this project is to establish a state-of-the-art research laboratory at NCATSU to grow and characterize amorphous thin films that are useful in semi-conductor devices. We are presently studying two film systems, nitride films and silicon dioxide films. The films are deposited on silicon substrate using plasma enhanced chemical vapor deposition.

During this reporting period over seventy deposition runs for nitride films were made. The films were grown using a 5% silane (mixed with argon) and nitrogen gases. A PD II A, manufactured by Technics, Inc. was used.

A schematic of the PD II A processing chamber is shown in Figure 1, A. Note that reactant gases enter the chamber below the heated deposition platen and flow radially to the exhaust port at the center of the platen. The system is symmetric except for the point in which the heating element feed-thru enters the platen. It has been found that the uniformity of the films were affected by the location of the film on the platen. The most uniform films are grown in position 1 and the star position, see Figure 1, B.

A. CROSS-SECTION OF PROCESS CHAMBER



1. Platen heater, lower plate of capacitor
2. Radial Gas Flow
3. Platen Heating Element Feed-Thru
4. Exhaust to Vacuum Pump
5. Upper Plate of Capacitor
6. Delrin Ring
7. Water Cooling
8. Power in

B. TOP VIEW OF HEATING PLATEN (with positions of substrate indicated)

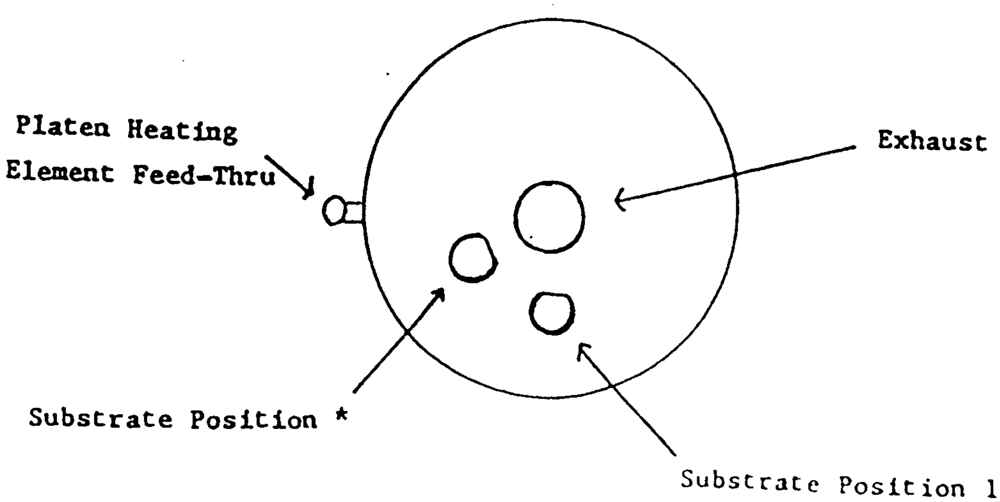


FIGURE 1

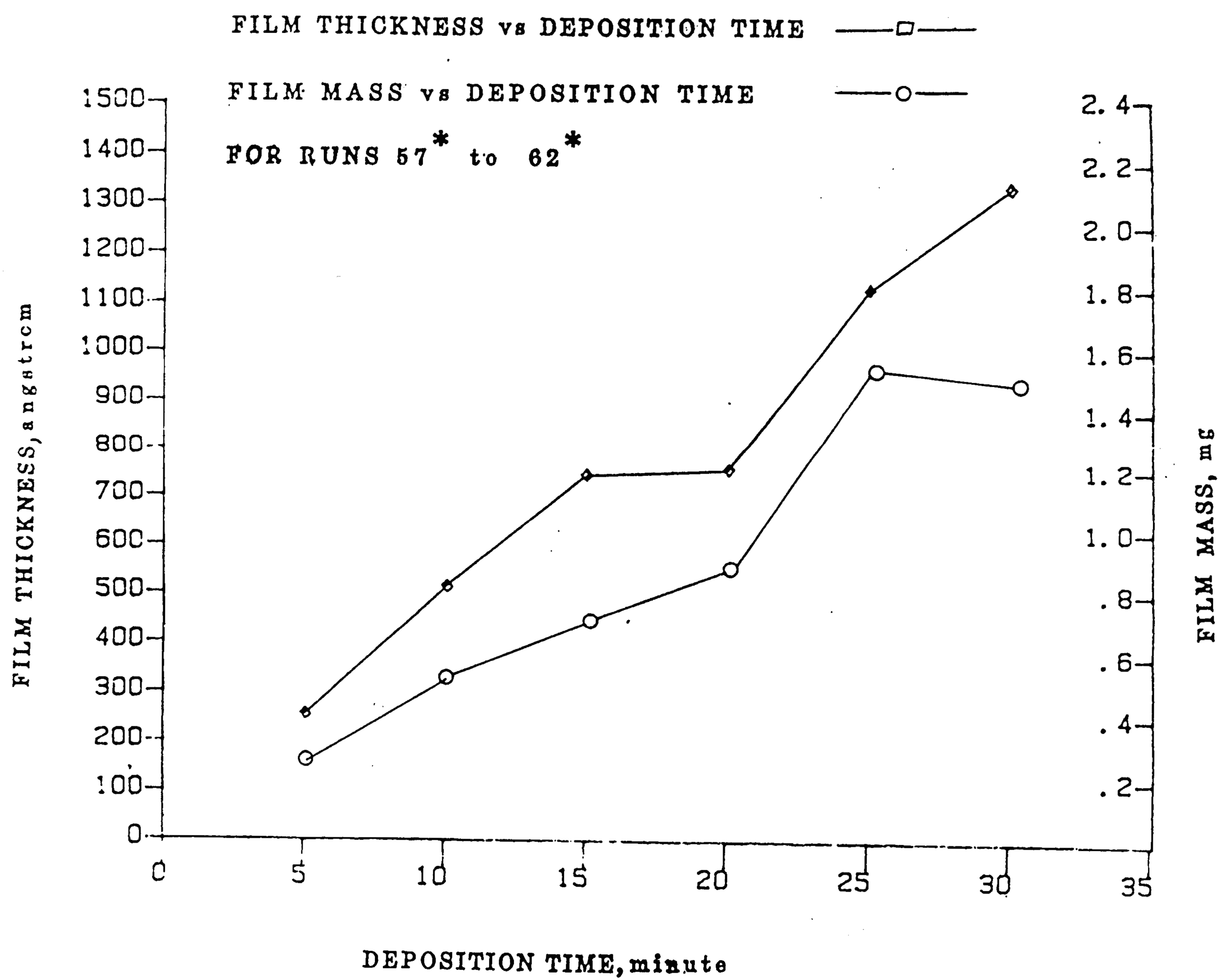
During this reporting period, a series of experiments were performed to determine the deposition rates for nitride films on N-type silicon substrate with (100) orientation and p-type silicon substrate with (111) orientation. In all of these experiments, the deposition parameters were

Nitrogen flow rate	-	40 sccm
Silane flow rate	-	100 sccm
Platen temperature	-	$200^{o}C$
RF Power	-	15 watts.

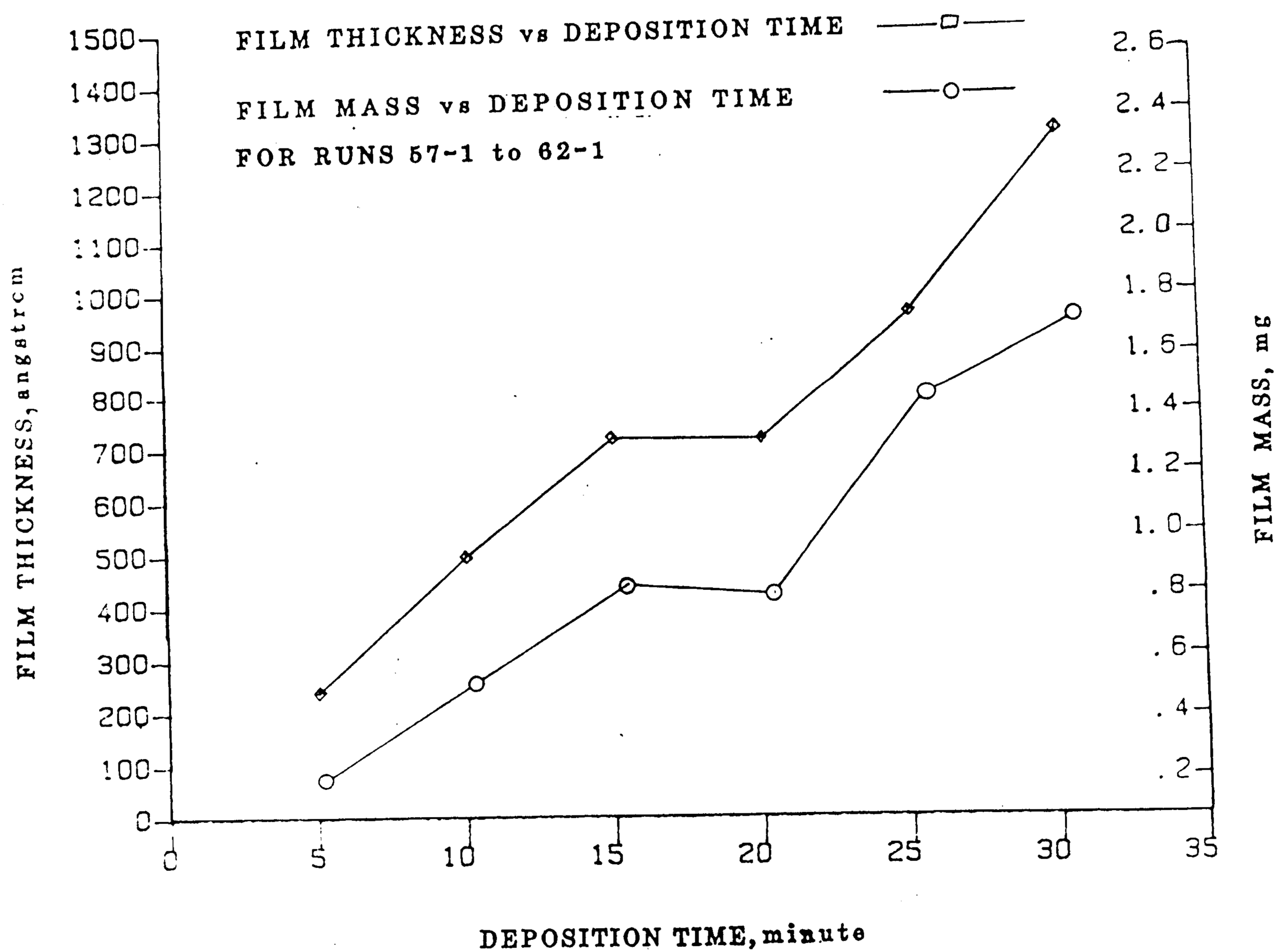
The mass of the deposited films were determined by weighing the substrate before deposition and the substrate and film after deposition. The index of refraction and the thickness of the films were measured at five positions on the film using a Gaertner, L117, ellipsometer. The index of refraction and thickness was averaged for each film.

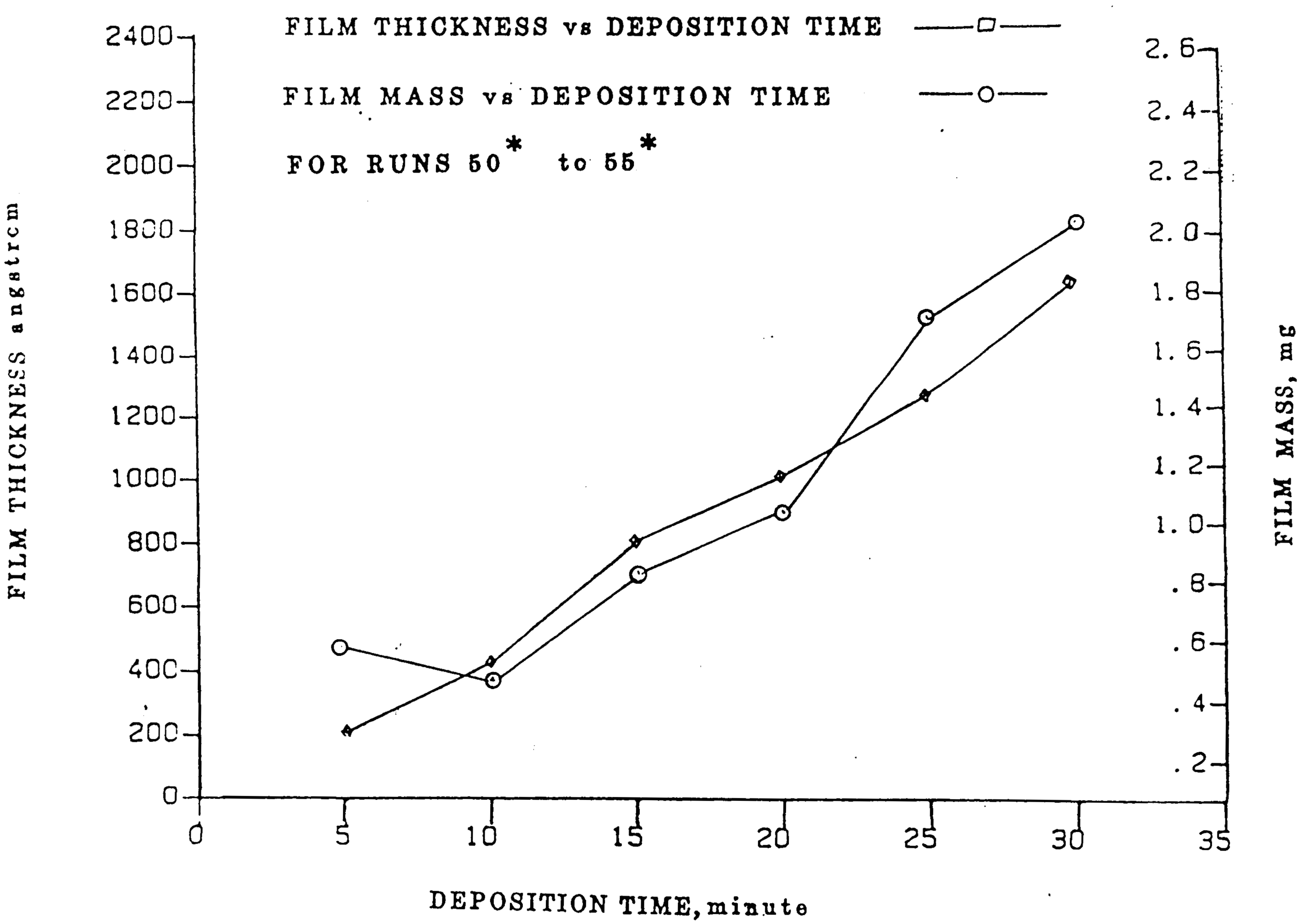
Graphs of thickness versus deposition time and film mass versus deposition time are shown on pages 5-7 and data tables for each series of runs are on pages 9-14. The series of runs 57*(film for run 57 at the star position) to 62* and 57-1 (run 57, position 1) to 62-1 were performed at the same time. The substrates were P-type, (111) orientation. The film thickness and time were leased squared fitted to a straight line to determine a deposition rate. The respective rates were 41 Å/minute and 38 Å/minute for runs 57* to 62* and runs 57-1 and 62-1. The deposition rate for the series of runs 50* to 55*, N-type, (100) orientation was significantly higher at 54 Å/minute.

A plot of index of refraction versus deposition time is shown on page 8 for all three series of runs. We are not in the process of studying uniformity and surface characteristics of the films.

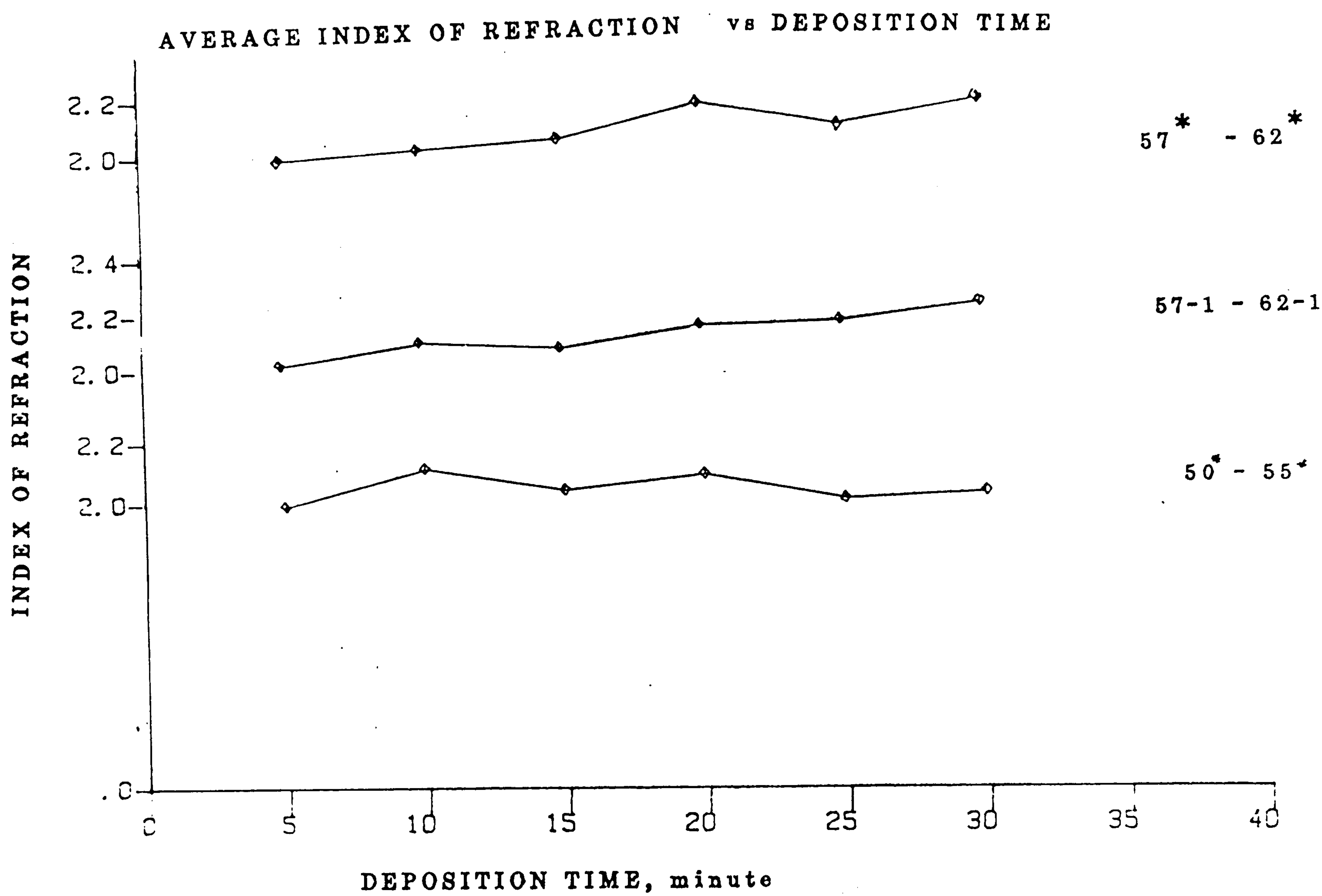


FILM THICKNESS vs DEPOSITION TIME
FILM MASS vs DEPOSITION TIME
FOR RUNS 57* to 62*
FILM THICKNESS, angstrom
FILM MASS, mg
DEPOSITION TIME, minute
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
0
5
10
15
20
25
30
35


FILM THICKNESS vs DEPOSITION TIME
FILM MASS vs DEPOSITION TIME
FOR RUNS 57-1 to 62-1
FILM THICKNESS, angstrom
FILM MASS, mg
DEPOSITION TIME, minute
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
5
10
15
20
25
30
35



FILM THICKNESS vs DEPOSITION TIME
FILM MASS vs DEPOSITION TIME
FOR RUNS 50* to 55*
FILM THICKNESS angstrom
FILM MASS, mg
DEPOSITION TIME, minute



AVERAGE INDEX OF REFRACTION vs DEPOSITION TIME
INDEX OF REFRACTION
2.2
2.0
2.4
2.2
2.0
2.2
2.0
.0
0
5
10
15
20
25
30
35
40
DEPOSITION TIME, minute
57* - 62*
57-1 - 62-1
50* - 55*

TABLE 1

INDEX OF REFRACTION, FILM MASS,
AVERAGE FILM THICKNESS FOR RUNS
50* TO 55*

RUN NUMBER	DEPOSITION TIME	MEASURED FILM THICKNESS FOR SELECTED POINTS (Å)	MEASURED INDEX OF REFRACTION FOR SELECTED POINTS	FILM MASS (MG)	AVERAGE THICKNESS (Å)	AVERAGE INDEX OF REFRACTION
54*	5	#1 290 #2 260 #3 320 #4 300 #5 260	#1 1.975 #2 2.25 #3 1.85 #4 1.95 #5 1.90	0.61	286	1.99
51*	10	#1 481 #2 443 #3 501 #4 540 #5 510	#1 2.1 #2 2.21 #3 2.1 #4 1.95 #5 2.19	0.49	495	2.11
50*	15	#1 860 #2 850 #3 885 #4 850 #5 890	#1 2.04 #2 2.05 #3 2.01 #4 2.06 #5 2.05	0.84	867	2.04
52*	20	#1 1060 #2 1060 #3 1180 #4 1000 #5 988	#1 2.13 #2 2.08 #3 2.0 #4 2.13 #5 2.13	1.05	1,060	2.09

TABLE 1, CONTINUED

INDEX OF REFRACTION, FILM MASS,
AVERAGE FILM THICKNESS FOR RUNS
50* TO 55*

RUN NUMBER	DEPOSITION TIME	MEASURED FILM THICKNESS FOR SELECTED POINTS (Å)	MEASURED INDEX OF REFRACTION FOR SELECTED POINTS	FILM MASS (MG)	AVERAGE THICKNESS (Å)	AVERAGE INDEX OF REFRACTION
53*	25	#1 1320 #2 1320 #3 1340 #4 1240 #5 1320	#1 2.0 #2 2.0 #3 2.0 #4 2.1 #5 1.95	1.71	1,310	2.01
55*	30	#1 1740 #2 1580 #3 1760 #4 1700 #5 1500	#1 2.0 #2 2.05 #3 2.0 #4 2.05 #5 2.05	2.01	1,660	2.03

TABLE II

INDEX OF REFRACTION, FILM MASS,
AVERAGE FILM THICKNESS FOR RUNS
57* to 62*

RUN NUMBER	DEPOSITION TIME	MEASURED FILM THICKNESS FOR SELECTED POINTS (Å)	MEASURED INDEX OF REFRACTION FOR SELECTED POINTS	FILM MASS (MG)	AVERAGE THICKNESS (Å)	AVERAGE INDEX OF REFRACTION
57*	5	#1 270 #2 230 #3 270 #4 250 #5 250	#1 2.05 #2 2.30 #3 2.00 #4 1.80 #5 1.80	0.27	254	1.99
58*	10	#1 510 #2 530 #3 510 #4 530 #5 480	#1 2.00 #2 2.00 #3 2.10 #4 2.00 #5 2.05	0.54	512	2.03
59*	15	#1 690 #2 730 #3 810 #4 740 #5 730	#1 2.15 #2 2.10 #3 2.00 #4 2.05 #5 2.05	0.73	740	2.07
60*	20	#1 760 #2 760 #3 760 #4 770 #5 710	#1 2.20 #2 2.20 #3 2.20 #4 2.20 #5 2.20	0.90	752	2.20

TABLE II. CONTINUED

INDEX OF REFRACTION, FILM MASS, AVERAGE FILM THICKNESS FOR RUNS 57* to 62*

RUN NUMBER	DEPOSITION TIME	MEASURED FILM THICKNESS FOR SELECTED POINTS (Å)	MEASURED INDEX OF REFRACTION FOR SELECTED POINTS	FILM MASS (MG)	AVERAGE THICKNESS (Å)	AVERAGE INDEX OF REFRACTION
61*	25	#1 1100 #2 1100 #3 1110 #4 1190 #5 1120	#1 2.15 #2 2.15 #3 2.15 #4 2.05 #5 2.10	1.55	1,120	2.12
62*	30	#1 1380 #2 1340 #3 1420 #4 1220 #5 1240	#1 2.15 #2 2.20 #3 2.20 #4 2.30 #5 2.20	1.50	1,320	2.21

TABLE III

INDEX OF REFRACTION, FILM MASS, AVERAGE FILM THICKNESS FOR RUNS 57-1 to 62-1

RUN NUMBER	DEPOSITION TIME	MEASURED FILM THICKNESS FOR SELECTED POINTS (Å)	MEASURED INDEX OF REFRACTION FOR SELECTED POINTS	FILM MASS (MG)	AVERAGE THICKNESS (Å)	AVERAGE INDEX OF REFRACTION
57-1	5	#1 240 #2 240 #3 250 #4 250 #5 210	#1 2.00 #2 2.00 #3 2.05 #4 2.00 #5 2.05	0.11	238	2.02
58-1	10	#1 540 #2 470 #3 530 #4 480 #5 450	#1 2.00 #2 2.05 #3 2.15 #4 2.15 #5 2.15	0.40	494	2.10
59-1	15	#1 730 #2 690 #3 800 #4 710 #5 650	#1 2.10 #2 2.10 #3 2.00 #4 2.10 #5 2.10	0.70	716	2.08
60-1	20	#1 730 #2 670 #3 750 #4 760 #5 660	#1 2.20 #2 2.20 #3 2.20 #4 2.20 #5 2.20	0.66	714	2.16

TABLE III, CONTINUED

INDEX OF REFRACTION, FILM MASS,
AVERAGE FILM THICKNESS FOR RUNS

57-1 to 62-1

RUN NUMBER	DEPOSITION TIME	MEASURED FILM THICKNESS FOR SELECTED POINTS (Å)	MEASURED INDEX OF REFRACTION FOR SELECTED POINTS	FILM MASS (MG)	AVERAGE THICKNESS (Å)	AVERAGE INDEX OF REFRACTION
61-1	25	#1 930 #2 810 #3 1000 #4 1040 #5 1000	#1 2.20 #2 2.20 #3 2.15 #4 2.15 #5 2.15	1.26	956	2.17
62-1	30	#1 1400 #2 1300 #3 1420 #4 1230 #5 1130	#1 2.15 #2 2.20 #3 2.20 #4 2.30 #5 2.30	1.50	1,300	2.23

STUDENT PARTICIPATION

Three graduate students and six undergraduate students (2 sophomores, 1 junior and 3 seniors) participated in the project. Student involvement consisted of the following activities:

-Student-delivered Research Papers

-Seminars

-Reading assignments

-Experiments or other projects

-Travel to scientific meetings

Student-Delivered Research Papers. Six students in our project have presented research papers at scientific meetings.

Robert Van Dyke, 1986 Meeting of Beta Kappa Chi Scientific Honor Society, at Norfolk, VA, hosted by Hampton Institute. Title: A Study of Reactive Plasma Deposited Thin Films. Received second place for papers presented in physics.

Michael Dentey, 1986 Meeting of Beta Kappa Chi Scientific Honor Society, at Norfolk, VA, hosted by Hampton Institute. Title: Calorimetry of the DO Detectors. Received third place for papers presented in physics.

Donald Anderson, (graduate student), 1985 HBCU Graduate Student Workshop, Langley Research Center, Hampton, VA. Title: A Study of Reactive Plasma Deposited Thin Films.

Muhammad Yaseen, (graduate student), 1984 Meeting of Beta Kappa Chi Scientific Honor Society, Atlanta, GA. Title: Current Developments in Plasma Deposition Research.

Bruce Alston, 1983 Fall Meeting of SACS-AAPT, N.C. A&T State University, Greensboro, N.C. Title: Refrigeration Subsystem for Superconductivity Magnets.

Reginald Goodwin, (undergraduate), 1984 Meeting of SACS-AAPT, Savannah, GA. Title: Goals and Current Research of Thin Film Lab at NCATSU.

Seminars. The students met biweekly with the project directors for a one hour seminar during regular school session and tri-weekly during summers. At these meetings progress reports on assignments were made and discussion of topics in semiconductor theory were held. Additionally, semiconductor terminology familiarization presentations were given.

Reading Assignments. The students in the project are at various levels in their educational programs. Our reading list covers a wide range of abilities. This growing list now includes:

-"Semiconductor Devices", by James Brophy (an old book).

-Several "A.I.P. News Release" articles. These are the author's popular version of his/her scientific paper. They are distributed by the American Institute of Physics.

-"Semiconductor International", a magazine.

-"Understanding Solid-State Electronics", a Radio Shack publication, developed by Texas Instruments Learning Center.

-"Microcomputer Dictionary", by C.J. Sippl.

-"Physics Today", published by American Institute of Physics.

-"Physics of Semiconductor Devices", by S.M. Sze.

-"Electronic Education", a magazine.

-Articles in Physics Journals.

-"Thin-Films - Interdiffusion and Reaction", edited by J.M. Poate.

-"Thin Films Processes", edited by John L. Vossen & Werner Kern.

-"Handbook of Lattice Spacings and Structures of Metals", by W.B. Pearson.

-"Instrumentation in Scientific Research", by Kurt S. Lion.

-"Guide to Safe Handling of Compressed Gases", 1983 Matheson Gas Products, Inc., third ed.

-"Introduction to Electronics", by Donald M. Hunten.

Experiments and Projects. Students have been actively involved in all areas of lab procedure, inclusive of assembling, appending and operating existing and incoming equipment. Participation in these activities has enabled the students, usually in two-member teams, to successfully perform the following experiments and special projects:

-Perform deposition runs of silicon nitride and silicon dioxide films using the PED system.

-Perform Pinhole Density Experiments

Experiments were conducted to determine the pinhole density of the deposited silicon nitride films on n and p type silicon substrates. In order to determine the number of pinholes a thin film of aluminum is deposited onto the substrate free of the silicon nitride film. On the film a 11 x 11 array of aluminum dots is deposited thereby forming 121 dielectric capacitors. By applying a voltage across each of the dielectric capacitors and measuring the amount of current flow through each capacitor the pinhole density is determined. Each of the aluminum dots is 1 millimeter in diameter and the array covers 57 percent of the deposited thin film.